Gissel

HOW TO USE

Portland Cement

From the German of L. GOLINELLI.

Published under the name of "*Das Kleine Cement-Bŭch,*" by the Association of German Portland Cement Manufacturers.

Translated by

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THIRD EDITION 1904

Price, Fifty Cents.

CEMENT AND ENGINEERING NEWS
CHICAGO,

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PREFACE.

A few years ago a very important and useful book, "Der Portland-cement und seine Anwendungen im Bauwesen," (Berlin, 1892), was published by the Association of German Portland Cement Manufacturers. This work includes the best information obtainable in reference to the testing and uses of Portland cement, and contains numerous illustrations showing the details of important examples of engineering work in which cement was employed. The cordial reception given this book by educated engineers led the association to undertake the preparation of a small pamphlet on the same subject, intended chiefly for the use of contractors and masons, which should give in simple and practical form the results of the best experience in the use of Portland cement. This pamphlet has lately been issued under the title of "Das Kleine Cement-buch," by the publishers of the *Thonindustrie Zeitung*. Over 22,000 copies were sold in Germany during the past few months, and a new edition has already been ordered.

Germany has long led the world in knowledge of the applications of cement, and most of our best information in regard to methods of manufacture, testing and uses of cement has come from that country. A full translation of this little pamphlet, representing, as it does, the latest German thought on the subject, will therefore doubtless be of interest to American cement consumers.

S. B. N.

SANDUSKY, O., March, 1899

HOW TO USE PORTLAND CEMENT.

From the German of L. Golinelli.

(Published under the name *Das kleine Cement-buch* by the Association of German Portland Cement Manufacturers.)

Translated by S. B. NEWBERRY.

It is an established fact that Portland cement is superior to all other hydraulic materials, natural or artificial, and for this reason it is widely distributed throughout the world. Its use would, however, be far greater if the knowledge of the applications and methods of testing of cement had kept pace, during the past ten years, with the improvements which have been made in quality and methods of manufacture. Even in sections where the manufacture of Portland cement has been extensively and successfully developed, and where one would consequently expect to find a certain amount of knowledge of the subject, a correct understanding of methods of testing and intelligent use of cement is often painfully lacking. The preparation and use of cement mortar, as practiced in many cases by masons or their helpers, is not only *imperfect* but *wasteful.* Better work could often be done with less material if careful methods were used. In the case of Portland cement such careful methods are especially necessary and profitable, and if they were followed the common complaint that Portland cement is too expensive would soon be no longer heard. Those who do intelligent and careful work have for a long time recognized the injustice of this charge. On the other hand, it is undoubtedly true that a high-grade material like

Portland cement, which in skillful hands may be usefully and economically employed for an immense variety of purposes, is especially liable to suffer from ignorance and misuse.

I. PROPERTIES OF PORTLAND CEMENT.

DEFINITION AND MANUFACTURE.

Portland cement is a material which hardens in the presence of water, prepared by burning at a sintering temperature an intimate mixture consisting essentially of lime (or carbonate of lime) and clay in certain definite proportions.

The raw materials, clay and carbonate of lime, are ground and mixed according to their character in either the wet or dry way. If the dry process is used, the mixed materials are moistened with water and molded into blocks. In the wet process the bricks are made from the wet material after it has been reduced to the proper consistency. After drying, the bricks of cement material are burned in suitable kilns to the point of sintering. The resulting "clinker" is ground to a fine powder; this is the finished cement.

CHEMICAL COMPOSITION.

The raw materials indicate the nature of the constituents of Portland cement. These are silica, alumina, iron oxide, lime and a small amount of magnesia. Alkalies and sulphates are are also always present, and are derived from the raw materials, which are never found pure in nature.

The presence of sulphuric acid (sulphate of lime) is also due to the sulphur in the fuel employed, and to the addition of a small amount of gypsum (sulphate of lime) for the purpose of making the cement slow-setting.

The composition of good Portland cement usually varies between the following limits:

Lime............................	58 to 65 per cent
Silica............................	20 to 26 "
Alumina........................	7 to 14 "
Magnesia	1 to 3 "
Alkalies.........................	traces to 3 "
Sulphuric Acid.................	traces to 2 "

According to the character of the raw material used, each manufacturer determines the correct composition of his product within the above limits, and this composition must be kept uniform by constant chemical analysis. The widespread belief that defective quality of cement is due to bad raw materials is seldom well founded; the fault is generally due to incorrect proportions and careless manufacture.

In studying the qualities of Portland cement, the following points are to be especially noted:

1. Form and fineness of grain.
2. Color and specific gravity.
3. Time of setting.
4. Hardening.
5. Strength.
6. Constancy of volume.
7. Hair cracks and shrinkage cracks.
8. Behavior under under extreme heat and cold.
9. Additions and adulterations.

FORM AND FINENESS OF GRAIN.

When examined under the microscope, particles of hydraulic lime have a more or less rounded form. Portland cement, on the other hand, shows thin leaflets of shale-like structure, like pounded glass. The high quality of Portland cement is in part due to this shale-like character, since greater density of mortar

results from the greater surface of contact and smaller proportion of voids between the particles.

As to fineness of grinding, it may be mentioned that the coarser particles of cement act practically like sand. It is therefore important that the grinding be not too coarse. A residue of not more than 5 per cent on a sieve of 75 meshes to the linear inch may fairly be demanded. The finer the grinding, the more sand can be used with the cement. It should be remembered, however, that poor cements, especially those too high in clay or imperfectly burned, are especially easy to grind to great fineness. Such cements may be generally recognized by their yellowish color and the spotty appearance of the work.

COLOR AND SPECIFIC GRAVITY.

The color of Portland cement should be a greenish gray; a yellowish or reddish gray tint indicates generally an inferior, light-burned product, or one to which under-burned or "dusted" material has been added.

Portland cement has a high specific gravity, a quality which contributes to its high value. No other hydraulic material has so high a specific gravity, or yields so dense and resistant a mortar. The specific gravity of Portland cement is from 3.12 to 3.25.

TIME OF SETTING.

When Portland cement is mixed with a suitable quality of water, a plastic paste is produced, which after a time becomes hard. The change from a semi-liquid to a solid mass is called setting, and the time required for this change, the *time of setting*. Cement is said to be *set* when it resists a light pressure of the finger nail on the surface.

It is of the greatest importance to know the time of setting of a cement which it is proposed to use, since a cement which has become set and has been again mixed up with water possesses little or no hydraulic energy. The mistake of mixing "set" mortar anew with water occurs only too often, and gives rise to the unjust complaint that the cement does not harden or possesses no strength. Great care should therefore be taken to mix up only such a quantity of mortar as can be conveniently used up in the time available; this can be easily managed when the time of setting is known. *Remnants of mortar which have become set should be discarded and must under no circumstances be again worked up with water.*

The determination of the time of setting is extremely simple, and may be made by any mason at the place where the cement is used. The best method is as follows:

The cement is mixed with water to a thick paste, worked one to two minutes with a spoon or trowel and spread out in the form of a pat on a glass plate. This pat should be about one-half inch thick in the middle and thin at the edges. As soon as the surface resists a light pressure of the finger-nail the cement is set. Since the temperature and the proportion of water used are of great influence on the result, it is best to have the cement and water at the ordinary temperature of 60 to 70 degrees, and to use not more than 30 to 32 per cent of water. The water must be clean. The pat should be protected from sunshine and drafts of air.

It is in the power of the manufacturer to produce either quick-setting or slow-setting cement, as may be required. A cement which requires two hours or longer to set is called slow-setting. Such cement is preferable

to that which sets quickly, on account of its greater strength. Quick-setting cement is used only for certain special purposes. Slow-setting cement can be made to set more quickly by using warm water, and also by limiting the water used to the smallest possible quantity. Among the substances which modify the time of setting may be mentioned:

Potash and soda, which hasten the setting. Sulphates and calcium chloride, which retard the setting.

In all cases the consumer will do well to notify the manufacturer what time of setting is desired, also for what purpose the cement is to be used. In this way many unjust complaints in regard to quality and many unnecessary expenses may be avoided.

HARDENING.

The set cement is capable of *hardening*, either in water or in air, and in a short time will acquire a high degree of strength. The processes of setting and hardening should not be confused. The latter begins at the point where the former ceases, and continues up to the highest strength which the cement attains after the lapse of many years.

As to the nature of the hardening process, to account for which various theories have been advanced, it need only be here stated that the hardening consists in chemical combination with water taking place under certain physical conditions. Among the most important of these conditions are *rest* during the setting and *protection from too rapid drying out.* The latter point can not be too strongly insisted upon. If the cement is deprived of the necessary water it can never reach its full hardness.

Portland cement attains within a few days a high degree of strength.

In the use of cement for building purposes, compression strength is the quality generally required. Cement is, however, generally tested only for tensile strength, owing to the fact that the tests of tensile strength can be made much more quickly, simply and cheaply than those of compression. There is also a definite, (though by no means exact) relation between the two tests, the compression strength being generally from 8 to 12 times the tensile strength.

The German official standards for Portland cement require that a mixture of one part cement with three parts normal sand shall show a tensile strength at 28 days of at least 227 lbs. per sq. in.

It is by no means simple, however, to make tensile strength tests in such a manner as to give reliable results. Complaints in regard to the quality of cement are often due entirely to faulty testing. In the preparation of briquettes, the temperature and quantity of the water used, the character of the sand employed, and the thoroughness with which the mortar is worked, are of immense influence on the results. The strength will generally be greater the less water is used; nevertheless it is always necessary to use such a quantity of water that it shall show itself on the surface of the briquette on tamping it into the mold. Long and vigorous working of the mortar increases its strength. In extensive building operations the use of mixing machines, especially pans with edge runners, is therefore highly advantageous.

CONSTANCY OF VOLUME AND CRACKING.

Strictly speaking, there is no such thing as constancy of volume, either in the case of mortar or stone, since

heat and cold, wetting or drying, modify the volume more or less. Portland cement also suffers changes of volume on hardening in water or in air. In the case of good Portland cement, however, these changes are extremely small and much less than those which occur in different kinds of stone. Bad cements, on the other hand, may show the dangerous quality of *cracking* or *swelling.* This shows itself in a strong expansion, which destroys the cohesion of the mortar and may cause its total destruction. Cement which swells badly, if laid between retaining walls, shows an immense power of expansion, even to the extent of forcing out the stones of the masonry.

The swelling does not show itself until after the setting. The worse the fault is the sooner it will appear. It shows itself, also, sooner in water than in air. In pats of cement kept under water this defect is to be noticed in the appearance of fine net-like cracks, or in worse cases in curving of the pats and the appearance of cracks around the edges. *It is characteristic of expansion cracks that they run from the edges toward the center of the pat and are widest at the edges and narrower toward the center.* These expansion cracks should not be confused with shrinkage cracks, mention of which will be made later.

The swelling of cement is always due to defects in manufacture. These are:

1. Faulty composition of the raw material, especially too high a proportion of lime.
2. Imperfect preparation of the raw material.
3. Imperfect burning of the clinker.
4. Too high proportion of sulphate or magnesia.

According to the German official requirements, a cement is considered to be constant in volume if a pat,

kept 28 days under water, remains perfectly flat and free from cracks. Swelling, due to too much lime, shows itself in this test with certainty within a few days or weeks. Cement containing too much magnesia, however, and burned to the point of sintering, shows noticeable expansion only after the lapse of long periods, extending even to several years. Only chemical analysis, or the guarantee of the manufacturer, can afford protection against the danger of expansion from excess of magnesia. Experience has shown that the presence of magnesia up to 3 per cent is entirely harmless.

In conclusion, two other peculiar appearances may be mentioned which are often erroneously considered to indicate swelling of the cement.

It is sometimes noticed that pats of neat cement, left in air, lose considerably in strength, and after a certain time become soft or friable, while similar pats kept in water are faultless in all respects. This is especially liable to occur in the case of pats made very wet and allowed to dry out immediately after setting. If, on the other hand, the pats are kept moist during the first stages of hardening, this defect is not developed.

Cracks, similar to those produced by swelling, are also produced when pats or briquettes are placed in water *too soon*, or before the setting is complete. To prevent this the official requirements specify that test-pieces shall be kept 24 hours in moist air before placing in water.

SHRINKAGE-CRACKS AND HAIR-CRACKS.

Portland cement mortar without sand, exposed to the air, diminishes in volume. If the drying takes place gradually and uniformly, as in a closed room, the cement shows no defects. Too rapid drying, in draughts

of air or in sunshine, without the precaution of keeping the cement moist, causes so-called *shrinkage-cracks.* These may be distinguished, in pats of cement, from expansion-cracks by the fact that they appear during the setting and show themselves as irregular curved lines extending over the middle of the pat. As already stated, the formation of shrinkage cracks is due to faulty use of the cement, and has practically nothing to do with its quality. Very finely ground cements are, moreover, more likely to show hair-cracks than those which are more coarsely ground.

Hair-cracks appear as fine lines on cement work which has stood some time. They are especially to be noticed on cement which has lain in the open air, and are due to frequent changes between wet and dry conditions. Hair-cracks and shrinkage-cracks occur chiefly when pure cement or mortar too rich in cement is used. They may be certainly avoided by the addition of sufficientsand and suitable treatment of the work.

RESISTANCE TO WEATHER AND BEHAVIOR UNDER EXTREME HEAT AND COLD.

Mortar made from pure cement is, strictly speaking, not weatherproof, owing to its tendency to form shrinkage-cracks and hair-cracks. Repeated expansion and shrinkage increases the number and size of these cracks, until finally under the action of water and frost the cement breaks to pieces. Complete weather-resisting qualities can be given to cement mortar only by the the addition of sand. One part sand to one part cement will be found sufficient.

The temperatures which are reached in warm, or even hot, climates have no bad influence on the hardening of Portland cement. The only precaution necessary

is to see that the water necessary for hardening is not removed too soon; or, in other words, that the work is kept sufficiently moist during the earlier stages of hardening. Even the temperature of boiling water is harmless to the strength of Portland cement, and a heat of 400 degrees to 500 degrees F. may be borne without injury. At a red heat it becomes soft and friable. Nevertheless it has been proved by long experience with Portland cement concrete that this material shows a high degree of strength and safety when exposed to fire.

Portland cement is less affected by frost than any other hydraulic material. If the cement is once fully set it may be exposed to strong freezing without any ill effect. It is only during the setting that injury can take place, and this is chiefly to be feared in case the mortar was made *too wet*, so that the freezing of the water forces the mass asunder. If water is sparingly used, masonry and concrete work may be done in extremely cold weather with good results. It must be remembered, however, that the setting and hardening of cement are much delayed by cold. Cement work done in freezing weather shows, therefore, but little strength at first, but finally reaches its normal hardness. Addition of salt to mortar in cold weather is generally to be avoided on account of the unsightly efflorescences which often result. It is better, when work in extreme heat or cold cannot be avoided, to warm the water and sand used and to reduce the water to the smallest possible quantity in order to hasten the setting of the mortar. If care is taken to allow no free water to separate, or that any excess of water is absorbed by dry stone, there is nothing to be feared even from extreme cold. Surface plastering with cement should, however, not be attempted in freezing weather.

On mixing cement with sea water the setting is delayed and decreased strength results. This is chiefly due to the action of the magnesium sulphate and chloride of the sea water on a portion of the cement; the hardening value of this part is therefore lost and the strength attained is less than with the use of fresh water. One might suppose that this action of the sea water salts would cause the strength of the cement to continue to fall off and that the work would finally fall to pieces. This is, however, not the case, owing to the fact that the penetration of the sea water into the mass is prevented by the great and constantly increasing density of the Portland cement mortar. A deposit of magnesia is also formed in the pores of the mass, and gives further protection against the entrance of the sea water. Portland cement is therefore unequalled for marine constructions. In all cases in which this work has been intelligently done Portland cement concrete has fulfilled all requirements most satisfactorily. In work exposed to sea water it is of the highest importance to give the concrete as dense and close-grained a surface as possible, since only such a surface is capable of permanently resisting the chemical action of the salt water and the mechanical force of the waves.

Portland cement is especially suitable for work of this kind, since uniform tests of tensile and compression strength are a guarantee of a uniform material which can safely be relied upon. This is by no means true in the case of puzzuolana cements, so-called slag cements and hydraulic limes, which are often of very variable quality.

ADDITIONS AND ADULTERATIONS.

Substances added to Portland cement may be divided into those which are intended to give it certain valuable

qualities, and others which are added for the purpose of fraud. In the first group are found *gypsum* and *coloring matters.*

The addition of gypsum (sulphate of lime) which should not exceed 2 per cent, is made for the purpose of causing naturally quick-setting cements to set more slowly. In this way the quality of the cement is improved and its strength increased. Additions of a higher proportion of gypsum are not admissable, as it tends to cause swelling.

Coloring matters are sometimes added to cement in order to make it suitable for decorative purposes. Mineral colors are practically always used. To give the cement a somewhat darker tint, especially for use in making cement wares, a few per cent of lamp-black is added. Nearly all coloring matters reduce the strength of the cement; ultra-marine, however, in small quantities, increases it. The red iron oxide of commerce, often used to produce a red color, frequently contains a considerable amount of sulphuric acid, and may cause swelling. Care should be taken in the choice of the coloring matters employed.

In regard to the production of *white Portland cement* it may be said that this has not hitherto proved successful, on account of impurities contained in the raw materials or derived from the fuel. The so-called white cements of commerce are for the most part inferior products which do not deserve the name of Portland cement. In consequence of its gray color, Portland cement cannot be made white by the addition of pigments.

From fraudulent and avaricious motives, blast furnace slag, limestone, shale, basalt, ashes, sand, etc., are added to cement. These are simply *adulterations,*

which always injure the quality of the product. These substances may be more or less easily detected, and their use, in consequence of the close watch kept by the association upon the product of its members, has of late practically ceased.

II. USE OF PORTLAND CEMENT.

PACKING AND WEIGHT.

(American weights are here substituted for the German weights given in the original pamphlet.—TRANSLATOR.)

Portland cement is packed in barrels and sacks. The barrel is of 400 lbs. weight and contains 380 lbs. (about 3½ cubic ft.) of cement. Sacks are generally one-fourth barrel, or 95 lbs. Since empty barrels and sacks are received by the manufacturer at a certain price, care should be taken to preserve them in an orderly manner. Empty sacks are most conveniently returned in bundles of ten each.

Barrels and sacks should be marked by the manufacturer with name, trade-mark and gross weight of package. Loss by sifting out and variations from standard weight to the amount of 2 per cent are allowable.

STORAGE (SEASONING) OF CEMENT.

Storage of cement improves its quality. If well protected and kept dry the cement gains in strength and becomes more slow-setting and more constant in volume. This so-called *seasoning* results from the action of the moisture and carbonic acid of the air. At the same time, owing to the disintegration of the coarser grains, the cement increases in fineness. If, however, cement is stored in a damp place it becomes caked, lumpy, partially set, and finally worthless. Dealers should keep this in mind and give close atten-

tion to the choice of a suitable place for storage. Portland cement bears long storage well, and even if packed in sacks may be safely kept in a dry place for many months.

If fresh, insufficiently seasoned cement is packed, an increase of volume takes place on long storage, and if the barrels are too completely filled or the hoops too strongly driven the hoops may be broken or the staves bent out. This may occur with faultless cements, and has nothing to do with so-called swelling or cracking.

CHOICE OF CEMENT AND CONCRETE MATERIALS.

Quick-setting cements are used for work exposed to leaching water, also for plastering and casts. For all other purposes slow-setting cement is preferable. Neat Portland cement is rarely used for mortar, and only in case the work is to remain constantly under water or in damp earth. In other cases more or less sand must be used to prevent shrinkage-cracks and produce a weatherproof mortar.

The character of the sand, gravel and stone used has great influence on the strength of the work. The sand must be sharp and pure; if it contains clay this must be removed by repeated washing. Very fine sand is generally objectionable; the best results are obtained with a graded sand, consisting of grains of various sizes, from fine to coarse. Stone and gravel for concrete must also be naturally clean or well washed, and must not be soft or chalky. Only clean water, free from mud, should be used for mixing cement mortar.

PREPARATION AND USE OF MORTAR.

If good results are to be obtained with Portland cement great care must be taken in the preparation of the mortar. If vessels which have been used for lime

or contain set cement are employed these must be well cleaned before use. As cement and sand are mixed in proportions by measure, it is a good plan to provide measuring vessels corresponding to the volume of the cement packages. The necessary figures are given in a previous paragraph under "Packing and Weight." Guess-work mixtures should never be made, for such methods not only give mortar of varying composition, but also cause unnecessary waste of cement.

The proportion of sand to be used varies with the character of the work; 1 to 2 parts sand to 1 cement are used only for work requiring extraordinary strength, great resistance to wear, or impermeability to water; 3 to 4 parts sand to 1 part cement are employed for ordinary weatherproof plastering, building mortar, foundations, artificial stone, etc.

More or less water should be taken according to the rate of setting of the cement, conditions of temperature, and kind of work in view. As a general rule as little water as possible should be used, and the mortar made plastic by prolonged, vigorous mixing. For the preparation of mortar the measured quantity of sand is spread out and the correct amount of cement scattered evenly over it; the two materials are then thoroughly mixed together. The necessary quantity of water is then strongly and thoroughly worked into the mass.

One of the chief rules in preparing mortar is that cement which has become set should never be worked up anew with water. For this reason no more mortar should be mixed at one time than can be used before the setting begins. Mortar which has become set and is again made plastic with water will never gain its normal hardness. Another important point is that the

brick or stone used for building must be thoroughly wetted before being laid up with cement mortar. The work should also be kept damp for a considerable time after it is finished, in order that the mortar may reach its full, stone-like hardness. The common practice of wetting bricks just before use by sprinkling with water from the mason's brush is quite insufficient. The bricks should be kept under water, in a vessel, until thoroughly saturated, and a stiff mortar used, in order that the brick should not be displaced after laying.

CEMENT-LIME MORTAR.

There are many kinds of work which require a quick-hardening mortar, but for which the great strength of a mixture of 1 cement with 1 to 4 of sand is unnecessary. The cost of such mortar is also, for many purposes, too high. A mixture of cement with 5 or more parts sand would give abundant strength, but such mortar works too "short" and adheres too imperfectly to the brick or stone; it cannot, therefore, safely be used.

In such cases the addition of slaked lime or hydraulic lime will correct the faults of poor mixtures of cement and sand, and will produce a cheap mortar, suitable for a great variety of uses. The addition of slaked lime allows the full advantage to be obtained from the use of good Portland cement, and makes it possible for this material to compete in price with cheaper hydraulic materials. Used in this manner, Portland cement may be employed with economy for the most ordinary purposes. The advantages of Portland cement lime mortar are its cheapness in comparison with other hydraulic materials, it rapid hardening, marked hydraulic properties, great strength on exposure to air, and remarkable resistance to weather.

The following mixtures for cement-lime mortar have been found by experience to be most suitable:

Cement	1,	sand	5,	lime	paste	½
"	1,	"	6 to 7,	"	"	1
"	1,	"	8,	"	"	1½
"	1,	"	10,	"	"	2

The above proportions are to be taken by measure. Hydraulic lime may be used in place of ordinary slaked lime.

Cement-lime mortar is prepared by making a dry mixture of the required quantities of cement and sand; milk of lime is then made with the necessary quantities of lime paste and water, and this milk of lime thoroughly mixed and worked in with the mixture of cement and sand.

The great advantages of cement-lime mortar for a multitude of purposes deserve to be more widely recognized than they are at present.

PORTLAND CEMENT MORTAR IN WATER AND IN AIR.

On account of its remarkable hydraulic properties, great strength, and durability, Portland cement mortar gives excellent results both in water and in air. The first essential to success is, however, that the mortar should be prepared and used suitably and intelligently for the special purpose in view. For work to be exposed to water, care must be taken to produce as dense and impenetrable a surface as possible; this may be accomplished by mixing the materials in suitable proportions. Ornaments, casts, etc., which are to be exposed to weather must never be made from pure cement; the same may be said of architectural artificial stone work. A certain proportion of sand must always be added.

In the preparation of water-tight mortar it should be remembered that the richer the mixture is in cement and the longer the mortar hardens the greater will be it impermeability to water. The reason of this is that in the process of hardening the mortar becomes constantly more dense, and the pores gradually close. The porosity of mortar is the greater, the thinner the layer employed and the higher the proportion of sand used. Coarse sand, also, gives a more porous mortar than fine sand.. For a coating $\frac{3}{5}$ to $\frac{4}{5}$ of an inch in thickness which requires to be immediately waterproof, the following mixtures are recommended:

Cement,	1, sand	(not too coarse),		1
"	1, "	1,	lime paste	½
"	1, "	3,	" "	1
"	1, "	5,	" "	1½
"	1, "	6,	" "	2

Which of these mixtures is to be employed depends on the nature of the work. By the addition of gravel or broken stone to the above mixtures water-tight concrete is obtained. From motives of economy, however, it is customary to make only the surface of the concrete of water-tight composition.

CEMENT PLASTERING AND PAINTING.

Experience has shown that cement plastering on walls and cornices, even when made with faultless material, is not always permanent. Sometimes the surface scales off in thin layers; in other cases blisters form and crack, or the whole layer of plastering may separate from the wall and fall off. In all such cases the work, and not the cement, is at fault. If walls are to be plastered with cement mortar it is indispensable that the surface be previously thoroughly cleaned from dust, dirt or lime-mortar, washed and repeatedly wetted. If the wetting

is insufficient the dry stone or brick take away from the cement the water necessary for hardening; if this happens the mortar adheres badly and never reaches its proper hardness. Wall-plastering which is exposed to weather should never be made very rich in cement for fear of the formation of shrinkage cracks. The more sand is used, provided the necessary strength is obtained, the better the plastering will resist the weather. Fine sand should be used, and for the purpose of avoiding hair-cracks and shrinkage cracks it is best to finish the surface with a felt polisher instead of a trowel or steel tool.

Cement plastering must be kept moist and protected from wind and sun. This work can be done most advantageously in spring; frost should be especially avoided. Some sands contain little particles of coal which are scarcely visible to the eye; these may have a very bad effect on the appearance of the work.

Cement work which is to be *painted*, either on account of hair-cracks or efflorescences derived from the alkalies and lime of the cement, or from any other cause, must be fully hardened and thoroughly dry. It is prudent to let the work stand a year before oil paint is applied. To insure the durability of the painting several methods may be used.

1. The surfaces are repeatedly brushed over with dilute sulphuric acid (1 part strong acid to 100 parts water), and allowed to dry before the paint is applied.

2. The surfaces are repeatedly and carefully washed with water, then after 8 days, saturated twice with linoleic acid (to be had from any druggist). After a few days, when the surface has grown hard, the oil paint is applied.

3. An excellent preparatory coating for oil paint is

a solution of common water-glass in 3 or 4 parts water. After two applications the surface is washed with water; after a short time the water-glass is again applied. When dry the paint can be used.

Even oil paint is, however, often of slight durability when exposed to weather. For work of great permanence the patent process of Dr. Golinelli, Koch and Adamy of Darmstadt, for preparation of cement work for stereochromatic painting, may here be mentioned.

CONCRETE.

One of the most important uses of Portland cement is in the making of *concrete.* This is a mixture of cement with sand and gravel or broken stone, with the addition of the necessary water. To obtain good adhesion of the materials, the water, sand and stone must all be *clean;* in some cases washing of these materials may be necessary.

The gravel or stone used must be at least equal in hardness to the cement mortar. Good gravel, basalt or hard lime stone are most suitable; soft sandstone or broken brick are to be avoided. The stone should not be above egg size. The proportions to be used depend on the nature of the work. When once determined they should be rigidly adhered to. For the preparation of concrete, the cement and sand are well mixed together on a dry platform; enough water is then mixed in to make the mortar about as moist as damp garden-earth; the gravel or stone, previously well wetted, is then added, and the whole thoroughly mixed by repeatedly turning over with shovels. The proportion of water must be so regulated that after prolonged and vigorous stamping the mass will become elastic and show a little water on the surface. The use of more

water is to be avoided, since it makes the mass less dense and lowers its strength. Too great stress cannot be laid upon thorough and careful stamping of the concrete into place, since in no other way can great strength and density be obtained.

With good Portland cement the proportion of 1 part cement and 3 parts sand, with varying amounts of gravel or stone up to 9 parts, will be found suitable; for some purposes poorer mixtures may be used.

Portland cement concrete finds many useful applications in constructions both above and below ground; for example, in foundations of all kinds, sidewalks, ceilings, walls, arches, cement wares, etc.

PREPARATION OF CONCRETE FLOORS, SIDEWALKS, STEPS AND CEILINGS.

For the construction of durable cement floors or sidewalks the foundation must be suitably prepared. For outdoor work on yielding ground a porous layer, at least 10 inches thick, of coarse gravel or slag should be laid, well rammed down and leveled. For indoor work on dry ground it is sufficient to level the surface and stamp it down firmly. Floors and sidewalks are generally built in two layers; a lower bed of concrete $2\frac{1}{2}$ to 4 inches thick, and a surface coat of richer mortar of a thickness of $\frac{3}{5}$ to $\frac{4}{5}$ of an inch.

The concrete layer may be made richer or poorer according to the service which the work must undergo. For heavy duty a mixture of cement 1, sand 3 and gravel 6 is recommended. In less important work cement 1, sand 5 and gravel 10 will answer. A suitable mixture for ordinary requirements is, cement 1, sand 4 and gravel 8 or broken stone 6.

The surface layer consists of cement 1, sand 1, and

must be spread over the concrete before the latter has set. Before spreading the top layer the concrete should be freed from loose material and its surface roughed up. The mortar is spread with a straight-edge and when sufficiently hardened is finished with a wooden tool. A grooved roller is used to produce a ribbed surface, especially in side-walk work.

When the work is finished and the cement is well set, the surface is carefully covered with a layer of sand 4 inches in thickness. This is moistened and kept in place for several weeks if possible. Only in this way can the formation of hair-cracks be prevented and a well hardened surface obtained.

Cement expands and contracts with changes of temperature, in the same way as iron, wood, sandstone and other materials. From this cause, if the necessary care has not been taken in the work, cracks will result, especially in wide surfaces. These may be avoided by dividing the flooring into smaller blocks, which should not exceed 4 to 5 square yards in area, and should be separated by strips of tar paper or by sand joints $\frac{3}{8}$ inch in width. The joints in the concrete must correspond with those cut in the surface layer. The division of the work into blocks is also to be recommended in concrete walls and curbs.

One of the most strikingly successful applications of Portland cement in building is its use for ceilings and staircases. Safety against fire, freedom from dry-rot, quickness of construction, and cheapness are some of the many advantages presented by this type of construction. A description of this and other similar applications of cement would, however, extend this pamphlet beyond desirable limits. Reference must, therefore, be made to special works on this subject.*

As already stated, cement work must be protected from too rapid drying out, since from this cause shrinkage cracks and lack of hardness and strength may result. A certain amount of water is absolutely necessary for the proper hardening of cement.

In case of sidewalks, ceilings, etc., the surface is to be kept covered with damp sand as long as possible. Cement wares should be kept under water, or stored in damp rooms, free from currents of air, and frequently sprinkled. Wall-plastering should be kept covered as long as possible with wet sacks or cloths. Cement casts which are to be exposed to weather, such as statues and architectural ornaments, must never be made of pure cement; a suitable proportion of sand is necessary, even for the surface. By the addition of fine, sharp sand the formation of unsightly hair-cracks is avoided without injury to the appearance of the work. The use of quick-setting cement with too little sand and much water, taking the objects too soon out of the moulds, and their delivery before they have acquired the necessary hardness, are serious errors. Such treatment was formerly much more common than it is at present, and has done much to cause cement wares to be regarded with undeserved suspicion. Since the introduction of more rational methods of manufacture, casts in cement have given full satisfaction, and owing to their cheapness are rapidly coming into extensive use. Architectural details for which sandstone was exclusively used twenty years ago, are now extensively cast in cement and find application in edifices of the most highly artistic character.

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*Portland cement und seine Anwendungen im Bauwesen; Berlin, 1892.
Cement in seiner Verwendung im Hochbau; Liebold, Halle, 1875.

In conclusion it may be noted that the remarkable properties of Portland cement make it suitable for an endless variety of uses. It is hoped that this brief sketch may serve to bring this valuable material into more extensive notice, and to contribute to a wider appreciation of its qualities and capabilities.